IMPACT OF CLEARCUTTING ON THE SOIL ENTOMOFAUNA

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The management of pine stands with the aid of clearcutting methods seems to be irreplaceable at present in poor sites. The use of clearcutting occurred, however, long before the ecology began to affect the biological foundations of forest sciences, and therefore it was continued without recognition of its biological consequences. The present status of knowledge on the flow of energy and matter through the forest ecosystems and on the soil-forming processes indicates the urgent need for an evaluation of the clearcutting system from the point of view of its influence on the biology of forest soils. Practical arguments supporting the need for reviewing our opinions regarding sustained forest management by the clearcutting system refer to the constant impoverishment of forest soils which makes it necessary to apply various forms of fertilization used in agriculture as a last resort to improve the productivity of pine stands. The use of fertilization as an indispensable agro-technical treatment of the forest is an alarming symptom of the depletion of the nutrient resources of forest soils.

While appreciating the favourable though short-time effect of the exposure of the soil through clearcutting on its acidity, as well as the acceleration of the process of mineralization of the organic water accumulated, and the improvement of water relations and aeration of the soil, we must mention that if the recurrent and rapid (every 80 to 100 years) removal of the stand should have a disastrous and prolonged effect on soil organisms, the future course of soil-forming processes would be seriously disturbed.

The regularity of soil-forming processes, and particularly the formation of humus which provides a reservoir of nutrients for woody plants, depends on the activity of the whole complex of soil organisms. Artificial exclusion of soil fauna from the process of decomposition of organic remnants almost precludes the formation of humus compounds. It is only by the simultaneous activity of fungi, bacteria, and soil fauna that a portion of organic remnants is transformed into humus and utilized by plants after its further decomposition.

Recent studies of various authors on microbiological consequences on the fauna of the use of clearcuts (2, 6, 8, 9, 11, 12, 15, 16 and others) on the one hand, and on the role of microorganisms and animals in the soil-forming processes (1, 4, 13, 17, 18) on the other, lead to such conclusions.

A drawback of the recent few studies on the effects of the practice of clearcuts on soil fauna was the restriction of observations to excessively brief periods following the cutting, which resulted in failure to consider the process of fauna regeneration, and the general treatment of individual taxonomic groups studied without the identification of species. The knowledge of changes in the quantitative relations of fauna in clearcut areas was under these circumstances sufficient for the elucidation of the qualitative aspects of the changes. Finally, the additional inaccuracy of some studies consisted in fixing the attention on the autumn and spring behaviour of the fauna in clearcut areas, which fails to give the proper picture of their quantitative relations due to the migration of animals.

Our studies on the problem discussed were carried out on a sample of one of the most numerous groups of the macrofauna of litter and accumulation horizon of forest soils, namely, on the sample of beetles from the Staphylinidae family. These insects do not determine the decomposition of litter, but their occurrence, usually as zoophags, is connected with the presence of larvae of dipterids, Apterygota, and other organisms playing an important part in soil-forming processes. Some Staphylinidae species are also satisfactory indicators of soil moisture, light conditions in forest floor, and decomposition processes. Due to these considerations and also to different food requirements of individual species, Staphylinidae were selected as a test group for studies on biocoenotic relations prevailing in the upper layer of forest soils.

Studies were carried out during the years 1962-1965 in the Peucedano-Pinetum association in the fresh pine stands of the Bialy Forest situated 100 km to the north-east of Warsaw, in the area of the Ostrów Mazowiecka forest district. On 30 study sites representing clearcuts, young plantations, and forest stands of various ages and characterized in detail as to site and flora, 875 samples of litter and soil with the area of 0.25 m^2 were taken. From these samples, Staphylinidae were isolated with the aid of sieves of the Reitter type.

RESULTS

Staphylinidae found on study areas were classified to the following classes of constancy for fresh pine forests: characteristic selecting F_3 - 7 species, forest accompanying F^2 - 28 species, non-forest accompanying F_1 - 36 species, foreign - F_0 - 32 species. No exclusive characteristic species were found, which indicated a poor differentiation of Staphylinidae fauna of the fresh pine forest in relation to other forest site types. During most of the production cycle of the stand a characteristic was the obvious domination of *Sipalia circellaris* Grav. and *Othius myrmecophilus* Kiesw. and the frequent ocurrence of *Mycetoporus splendidus* Grav.

Fresh pine forests occur on sandy soils in which it is frequent to find moisture fluctuations close to the lower values of this factor, and this may restrict the occurrence of polyhgroy- and mesohygrophilous organisms.

This is why the ecological amplitude of numerous Staphylinidae species is interrupted in the habitat mentioned. Hence, the consequences of forest fellings with the clearcutting system and the resultant dryness of the soil concern in the first place forest mesohygrophilous species and may be registered in various periods of the life of the stands. Four such periods were identified: I - clearcuts in one-year old plantations, II - 2 to 11-year old plantations, III - 12 to 22-year old thickets, IV - stands more than 22 - years old. During the IVth period there occurs a Staphylinidae community with *Sipalia circellaris* and *Othius myrmecophilus* as dominant species. During the subperiod IVa, including pole-sized stands, *Conosoma immaculatum* Steph. is an indicator species, while during the subperiod IVb, in maturing and mature stands, an increased occurrence of *Tachyporus hypnorum F.* and *Xantholinus tricolor F.* provides a characteristic feature. During the IVth period, all characteristic selecting species occur and the mean density of individuals amounts to 16/m^2.

Felling of 80- to 100-year old stands and ploughing furrows for regeneration lead to the degeneration of the community described.

No indicator species were identified during the Ist period. It is characterized by a gradual elimination of specialized Staphylinidae inhabiting forest litter, particularly zoophags, in favour of eurytopic forms with high ecological plasticity and broader trophic specialization (hemi- and parazoophagy). Numbers of the species from the class F_3 and F_2 (characteristic selecting and forest accompanying ones) attain their lowest status during August and September and afterwards increase slightly. On the other hand, in clearcuts and in 1-year old plantations, numbers of species from the F_1 class (non-forest accompanying ones) increase gradually. The mean density of individuals amounts to 8.4/m^2.

The essence of fauna transformations under the impact of clearcuts is manifested during the IInd period – young plantations. It is characterized by a great difference in species composition and particularly in the quantitative composition of Staphylinidae when compared with the community during other stages of the forest production cycle. Hence the phase of the Staphylinidae community during the IInd period was called the critical phase, because its composition reflects a well advanced isolation of the forest entomofauna. With a generally low index of density (5.6 individuals/m^2) *Tachyporus chrysomelinus* L. prevails and *Stenus ater* Mann. and *Astenus longelytratus* Palm. are indicator species. During this period *Sipalia circellaris* Grav. disappears almost entirely; the occurrence of *Othius myrmecophilus* Kiesw. in 2- to 4-year old plantations is sporadic and in 5- to 11-year old plantations was not recorded. The occurrence of species from classes F_3 and F_2 is here generally sporadic and results from habitat contact with neighbouring stands. High temperatures of surface soil layer eliminate the Euro-Siberian entomofauna typical of pine forests and at the same time cause the arrival from the forest edge and compartment lines of stenothermal species representing a European and southern Palearctic type of distribution. The community composition indicates a lack of biocoenotic stabilization in the surface soil layer, the most critical moment occurring on two occasions. The first time is in 4- to 5-year old plantations, when faunistic elements of the cut stand disappear entirely, and the second time in10- to 11-year old plantations when forest species are still lacking and the number of eurytopic and stenothermal species in connection with the closure of the tree canopy undergo gradual decrease.

Within 2-3 years after the complete closure of the canopy there begins the IIIrd period of regeneration of the community of litter and soil inhabited by *Staphylinidae*. During the long (10 to 20 years) time interval dividing period II from period IV there occur very significant quantitative and qualitative changes in the community, resulting from changes in habitat, particularly from shading and increased soil moisture, increased fall of litter, and the replacement of the xerophilous vegetation of young plantations by mesohygrophilous forest species. The effect of the mentioned changes increases from year to year and their direction consequently leads from eurytopic photophilous and stenothermal entomofauna of the young plantations to the specialized forest entomofauna of older stands.

The numbers of the species from genera Tachyporus and Xantholinus are regularly reduced, while *Sipalia circellaris* Grav. and *Othius myrmecophilus* Kiesw. appear ever more frequently. In thickets, *Mycetoporus splendidus* Grav. prevails, however, while *Stenus geniculatus* Grav. is an indicator and co-dominant species. These are species with rather broad ecological amplitude, but not eurytopic ones. During the IIIrd period there is an increase in the number of species and in density from 8.4 to 10.4 individuals/m^2. Indices of the domination and

density of species from class F_1 (non-forest accompanying) and F_3 (characteristic selecting) are levelled as an exclusive result of the increase in numbers of the latter. This shows a progressive regeneration of forest fauna during this period. The rate of the formation and composition of the Staphylinidae community in thickets depends to a considerable extent on the tree canopy and the soil-forming process and takes place in the presence of other organisms participating in this process. Hence, the raking of litter, intensive thinning of thickets, etc. may seriously inhibit the process of forest fauna regeneration.

If there are no particular disturbances in the forest habitat the complete regeneration of a community is attained between the years 20 and 30 of the life of the stand and thus at the stage of young growth. In regard to the fauna the period of regeneration is determined by the takeover of domination in the Staphylinidae community by *Sipalia circellaris* Grav.

DISCUSSION

The generalization of the results obtained would benefit from a comparison with results of similar studies concerning other taxonomic groups of soil animals.

The most conclusive in this respect are the results of studies by GRETSCHY (6), KARPINEN (11), HUHTA *et al.* (8, 9), KUDRIASZOWA (12), although all of them were carried out on sites richer in water and more fertile, thus making easier the processes of regeneration of the soil fauna.

In spruce stands of Finland the density of soil animals following the felling of stands was subjected to strong alterations during 4 years, after which it started to return to the status characteristic of older stands which, however, was not attained even after 10 years. From among animals participating in the decomposition, the numbers of Enchytraeidae and Collembola increased in the clearcut, while the numbers of Oribatei and other Acarina, and that of Lumbricidae, decreased. In such circumstances the stabilization of the Acarina community may take even circa 30 years. An increase in Enchytraeidae and Collembola numbers occurred under favourable conditions of soil moisture (higher than in a stand) and with the lack of competition from Acarina, restricted by adverse conditions for the development of fungi carrying out the preliminary decomposition of spruce needles, which only then become the food for Acarina. An increase in Collembola (concerning Enchytraeidea other data are lacking) cannot be considered a rule. In Alpine spruce stands their numbers decrease by half in clearcuts and after 3 years their further elimination was recorded. Numbers of invertebrates in oakwoods growing on rich sites are lowest during the second year following felling. Numbers of great saprophags, e.g. earthworms, are particularly reduced under such conditions.

These studies have provided us with conclusions important for our considerations, namely, that clearcutting to a serious degree affects animals participating in soil-forming processes, while altering (as a rule restricting) their numbers, and that the time of the regeneration of forest fauna in clearcut areas is not strictly defined.

The results of other studies, moreover, show that the afforestation of recultivated areas brings about an intensive increase in the processes of zoogenous decomposition and beneficial changes in their quality. For example, the afforestation of dumps of brown coal caused the alteration of the "moder" type of decomposition prevailing during the third year into the "mull" type found between years 7 - 10 of the existence of tree plantations established there (5).

These data provide additional arguments on the progressive role of the fauna in the soil-forming processes along with the growth of forest stands.

Our studies, substantiated thus by the possibility of generalization, including soil animals decomposing forest litter, indicate that the use of the clearcutting system in pine stands in sites of fresh coniferous forests eliminates entirely or to a considerable degree the typical forest Staphylinidae for about 1/4 of the average production cycle of stands. An expression of the disturbance is the elimination of forest fauna and the increase in importance of eurytopic species. It would be, however, most dangerous, if the predominance of non-specialized species with broad intervals of tolerance to environmental factors could lead to further simplification of biocoenotic links in forest habitats, since in naturally poor ecosystems these species begin to play an important and even decisive role in the control of the numbers of specialized species. This was found, among others, by KACZMAREK (10) in relation to hemizoophags of soil macrofauna. The increase of hemizoophagous Staphylinidae as a result of the use of clearcutting is quite symptomatic in this respect. Results of research permit to assume that the increase in numbers of eurytopic species in litter-inhabiting communities of Staphylinidae (and undoubtedly other animals too) in pine forests occurred relatively recently and has been emphasized now under definite conditions leading to the elimination of forms adapted to the given biocoenosis. This may result in a chain reaction and bring about an extreme impoverishment of soil organism communities. The narrowing of the network of biocoenotic links and their simplification is particularily dangerous to the soil environment, where for the regular course of the soil-forming process the whole complex of living organisms specific for each biotope is indispensable. Lack of these organisms leads to the impairment of the fertility and efficiency of forest soils, which was well documented in a sample of brown soils from southern France, where felling in oakwoods brought about the irrevocable destruction of certain endemic species of soil animals (3,7).

It is, therefore, probable that regressive changes of periods I and II, and particularly the regeneration of communities of forest soil organisms will, with every new production cycle of stands involve ever longer time intervals, also due to the permanently aggravating conditions of the soil-forming process following secondarily the initial intensive (wasteful) mineralization of organic in clearcut areas.

If the elimination of forest species of the soil fauna as a result of the use of the clearcutting system still is not a common phenomenon, this is so because intensive forest utilization is of short duration when compared with the age of this formation. In this connection, numerous forest biocoenoses preserve a sufficiently strong regeneration ability.

CONCLUSIONS

1. The number of scientific publications concerning the impact of the clearcutting system on soil fauna is slight. They do not consider, or do so to a very limited degree, the qualitative aspect of faunistic alterations occurring as a result of forest felling, and are restricted to general quantitative data. Insuffient attention was paid to processes of the regeneration of forest fauna in clearcut areas.

The author's studies on Staphylinidae covered the mentioned aspects.

2. The use of the clearcutting system leads to enormous disturbances in the composition of soil fauna.

3. Alterations which occur in the Staphylinidae community under the impact of clearcuts are of negative character in poor sites of fresh coniferous forests. Negative features are maintained during ca 1/4 of the production cycle of the forest stands. Predominance of eurytopic forms, with simultaneous elimination of specialized forest soil species and low density of individuals during this time, indicate a strong biocoenotic disturbance in the forest soil.

4. Studies by various authors have revealed that the majority of animal groups directly participating in the decomposition process after a short-term increase in numbers during the first year after clearcut show afterwards a reduction in numbers. The regeneration of this fauna is not known sufficiently. Contemporary results permit to assume that it covers a period of between 10 and 30 years.

5. Recognized on the sample of Staphylinidae, the fact of the preference of species with broad habitat and food specialization under the impact of clearcutting system may lead to further biocoenotic disturbances in the soil environment, while prolonging the period of regeneration of forest fauna, including the fauna participating in decomposition. If this hypothesis turned out to be true, then one should expect permanent disturbances of the soil-forming processes in clearcut areas. The disturbances would be manifested by decreases in the productivity of stands of the IInd age-class (and possibly older ones).

Progress in the studies aimed at the solution of the problem outlined seems indispensable.

6. Even at present, with the background of the results of recent studies, one may state that for the sake of forest management such methods ought to be selected which would bring about the greatest possible shortening of the process of regeneration of the soil fauna destroyed in clearcuts, and the rapid reactivation the soil-forming process.

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Summary

Recent studies of various authors on the biological consequences of forest fellings and on the role of organisms in soil-forming processes indicate the necessity to initiate works aimed at the determination of the duration of forest soil fauna regeneration in clearcuts.

The studies presented were carried out in pine forests in the vicinity of Warsaw on a sample of a numerous group of litter macrofauna, namely Staphylinidae (Coleoptera).

The Staphylinidae community, with the dominant species Sipalia circellaris Grav., occurs in older stands. The felling of forests with the use of the clearcutting system brings about the degeneration of the community within one year. Eurytopic and Xerophilous species prevail in 2- to 11-year old plantations. The period of forest entomofauna regeneration lasts from the 12th to the 25th year of the life of the stand and is completed with the restoration of the domination structure in the Staphylinidae community characteristic of mature stands.

Alterations in the composition of the community occurring under the impact of clearcuts are of negative nature and are maintained during 1/4 to 1/3 of the average production cycle in pine stands growing on poor sites.

The hypothesis was put forward that the described negative faunistic features in the soil environment may aggravate with each new production cycle of stands managed according to the clearcutting system, due to consistently worsened living conditions for the forest entomofauna. These conditions favour species with broad environmental and trophic specialization.

Since other animals active in the soil-forming process are also being restricted in clearcuts, forest management ought to select methods which would lead to a maximum shortening of the duration of the soil fauna regeneration in clearcut areas and the rapid reactivation of the soil-forming process.

Resumen

El impacto de la tala rasa en la entomofauna del suelo

Recientes estudios realizados por varios autores sobre las consecuencias biológicas de la tala de bosques y sobre el papel de los organismos en el proceso de formación del suelo, demostraron la necesidad de iniciar trabajos tendientes a determinar la duración de la regeneración de la fauna del suelo forestal en las zonas sometidas a raleos.

Los estudios presentados se realizaron en los bosques de pinos de los alrededores de Varsovia y se basaron en un grupo numeroso de macrofauna de los desechos vegetales que cubrían el suelo, a saber Staphylinidae (Coleoptera).

La comunidad de Staphylinidae, *con las especies dominantes de* Sipalia circellaris Gray, *se encuentra en los rodales de mayor edad. La tala del bosque utilizando el sistema de tala rasa, acarrea la degeneración de la comunidad en sólo un año. Las especies euritópicas y xerófilas predominan en las plantaciones de 2 a 11 años de edad. El periodo de regeneración de la entomofauna forestal, se extiende desde el 12º al 25º año de vida de un rodal y termina con el restablecimiento de la estructura dominante característica de la comunidad* Staphylinidae *para los rodales maduros.*

Las alteraciones de la composición de la comunidad, causadas por los raleos, son de naturaleza negativa y se mantienen durante 1/4 a 1/3 del ciclo medio de producción en los rodales de pinos de los lugares pobres.

Se ha formulado la hipótesis, según la cual, los rasgos negativos descriptos de la fauna en el medio del suelo pueden empeorar con cada nuevo ciclo de producción de los rodales ordenados según el sistema de tala rasa, a causa del constante desmejoramiento de lascondiciones de vida para la entomofauna del bosque. Esas condiciones favorecen a las especies que poseen una gran especialización trófica y ambiental.

Dado que otros animales igualmente activos en el proceso de formación del suelo, son restringidos por la tala rasa, el ordenamiento forestal debería seleccionar métodos que conduzcan a acortar al máximo la duración de la regeneración de la fauna del suelo en las zonas sometidas a tala rasa, a fin de activar eventualmente el proceso de renovación del suelo.

Résumé

Incidence de la coupe rase sur l'entomofaune du sol

De récentes études réalisées par divers auteurs sur les conséquences biologiques de l'abattage des forêts, et sur le rôle des organismes vivants dans le processus de formation du sol, ont montré la nécessité de travaux visant a déterminer la durée de la régénération, de la faune du sol forestier dans les zones éclaircies.

Les études présentées ont été menées à terme dans des forêts de pins voisines de Varsovie, et se sont fondées sur un exemple fourni par un groupe nombreux de la macrofaune des débris couvrant le sol, à savoir les Staphylinidae (Coleoptera).

La communauté des Staphylinidae, *avec les espèces dominantes de* Sipalia circellaris *Grav., se trouve dans les peuplements âgés. L'abattage de la forêt en utilisant le système de coupe à blanc entraîne la dégénération de la communauté en un an seulement. Les espèces eurytopiques et xérophiles prédominent dans les plantations âgées de 2 à 11 ans. La période de régéné-ration de l'entomofaune forestière s'étend de la douzième à la vingt-cinquième année de vie d'un peuplement et s'achève avec la réintégration de la structure dominante caractéristique de la communauté de* Staphylinidae *pour les peuplements âgés.*

Les altérations, dans la composition de la communauté, à la suite de l'impact produit par l'abattage, sont de nature négative et se maintiennent pendant un quart à un tiers du cycle moyen de production dans les peuplements de pins des sites pauvres.

On a formulé une hypothèse selon laquelle les aspects négatifs décrits de la faune du sol peuvent empirer avec chaque nouveau cycle de production des peuplements aménagés suivant le système de coupe à blanc, du fait de l'aggravation constante des conditions de vie de l'entomofaune de la forêt. Ces conditions favorisent les espèces ayant une rande spécialisation trophique et environnementale.

Étant donné que d'autres animaux également actifs dans le processus de formation du sol sont lésés par la la coupe à blanc l'aménagement forestier devrait sélectionner des méthodes conduisant à réduire le plus possible de la durée de régénération de la faune édaphique dans les zones coupées à ras afin d'activer eventuellement du sol.